Document title:

H4.2C MULTIBEAM AND INTERFEROMETRIC OPERATIONS

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INTRODUCTION

The calibration of various instruments is very important if you want to be sure your measurements are correct. In the hydrography almost all instruments you use can and must be calibrated. In this report I will mostly talk about the calibration of a multibeam and in specific the calibration of the multibeam at site. Calibration of a multibeam is one of the keys to get good data when doing a survey.

For the Standard of Competence reports we had to choose three different subjects. This SOC reports is about Integration and Calibration. In the document where all the different SOC subjects are described, this subject is described as follows: Explain the effects on depth and position uncertainty of uncertainty in sensor locations, system latency, and alignments within the vessel reference frame. Define the "patch test".
I chose this subject because the calibration of equipment is a very important part in the hydrography and I would like to learn more about it. During my internship I have to do a patch test multiple times, so I think I will have enough information and results to put in this report.

In this report I will first tell something about calibration in general, then about the calibration of a multibeam and at last I will talk about the calibration of the multibeam used at the project in Kaohsiung and Mailiao, Taiwan.

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1 CALIBRATION IN GENERALION

If you calibrate a system or device you compare it with a standard to establish the properties. When a device is calibrated the deviation of that device is being established. This can be done by comparing the device with a referential or measured model.
The measured data can get corrected with the deviation of the device to get accurate measurements. When the measured deviation gets corrected it is called an adjustment. When you have calibrated a device you can determine if the device still meets the requirements. For example a requirement of a device can be that it needs to measure something within a range of 1 cm, when doing the calibration you can make sure the device will be able to accomplice this.

Just like all other measurements, also a calibration has a certain inaccuracy. The inaccuracy always needs to be reported by the measurements. For example you have to read something of a tape measure and you can measure upon millimetres that will say there will be an inaccuracy of +- 1 mm.

In the hydrography lots of instruments used for measurements can and must be calibrated to get good calculations as said above. A few of these hydrographic instruments are the multibeam, the singlebeam, the GPS etc. In this report I will be focussing on the calibration of a multibeam.

A fun fact about calibration is that the term originally comes from the arms industry. The inside diameter of the barrel of a firearm is still called ‘calibre’. If the calibration is required by law it’s a ‘standardisation’ or in Dutch an ‘ijking’.

2 MULTIBEAM CALIBRATION

A multibeam is a device used in the hydrography to detect the seafloor. The multibeam sends sound signals in the water to detect the seafloor. The multibeam, in contrast to the singlebeam, sends multiple signals in different angles in the water. This results in a vertical range under the ship. In the image below is the difference between the multibeam footprint and singlebeam footprint shown.

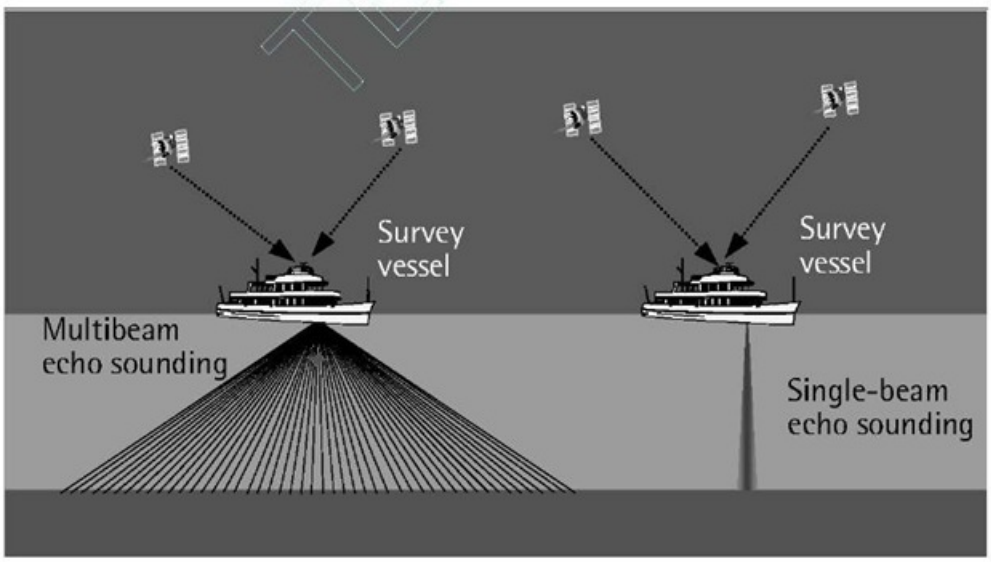


Image 1 Footprint Multibeam and Single-beam

The sound signals will hit the seafloor and bounce back to the ship, where a transducer will receive these signals. Together with the sound velocity of the water, the depth of the seafloor can be determined.

When you know how fast the sound signals move in the water and how long it takes for the signals to be received by the transducer the depth can be calculated.
Besides the sound velocity there is also a second parameter, the transducer depth (dt). The multibeam will be placed under the water surface, not exactly in line with the water surface.
The multibeam will only measure the depth between the transducer and the seafloor, but you want to know the depth between the water surface and seafloor. The following equation can be applied to calculate the depth between the water surface and the seafloor:

$$D = \frac{v*t}{2} + d_t$$

In which
D = Depth in reference to the water surface
v = Sound velocity
t = Time between sending and receiving a signal
dt = Transducer depth

Before you can start to measure with a multibeam you should calibrate the sensor to find the mounting angle errors. These errors are the roll, pitch and heading. To find these errors, a particular method should be used.

2.1 HOW TO CALIBRATE A MULTIBEAM

To find the roll, pitch and heading particular patters should be sailed. I will explain how to find each of these mounting angle errors. This method of sailing can be used for every multibeam calibration.

GPS latency delay

To find the latency delay there has to be sailed two lines over a slope or feature. One time at survey speed one time at half of survey speed.
Shown below is the method that should be used when sailing.

At this project we did not have to find the latency delay. The PPS pulse on board made sure all the equipment was synchronized with each other so there was no latency delay.

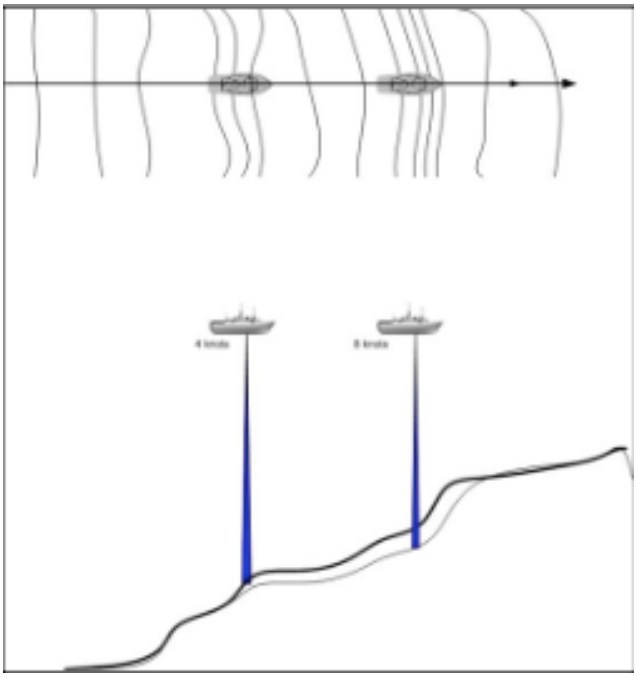


Image 2 Sailing method latency delay

Roll

To find the roll offset you have to sail over a flat sea area. There has to be surveyed one line two times in opposite direction. This has to be done at survey speed. If there is something wrong with the settings of the roll offset you will see two seafloors in opposite direction.
Shown below is the method that should be used when sailing.

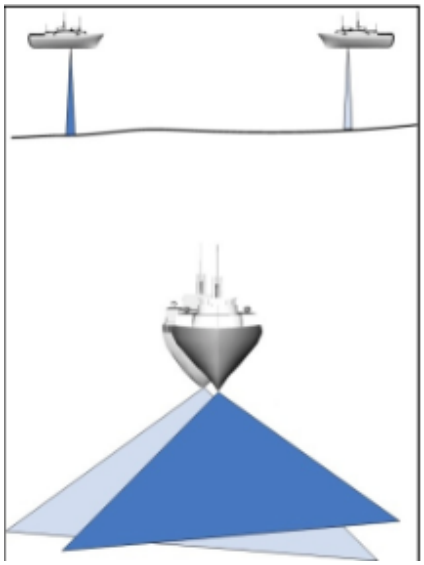


Image 3 Sailing method roll

Pitch

To find the pitch offset you have to sail over a steep slope or a feature on the sea floor. There has to be surveyed one line two times in opposite direction. This has to be done at survey speed. With this test it is very important that you pass the exact same part of the slope or feature.
Shown below is the method that should be used when sailing.

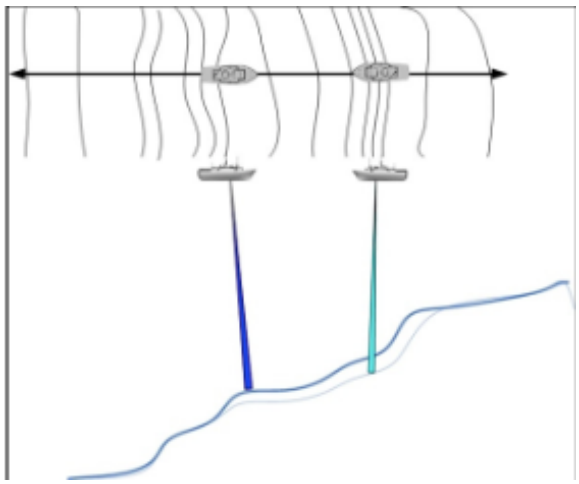


Image 4 Sailing method pitch

Heading

The heading test is said to be the most difficult to find. To find the heading easier you have to sail over a feature instead of a slope. There has to be sailed two line in the same direction, but one time the SB beams will detect the feature and the other time the PS beams will. This is also a reason why to use a feature instead of a slope to find the heading offset.
Shown below is the method that should be used when sailing.

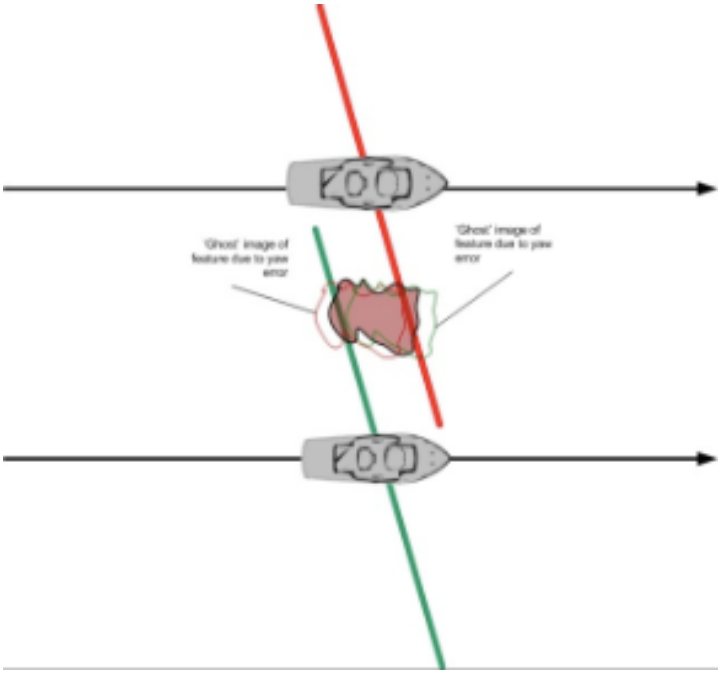


Image 5 Sailing method heading

2.2 RESULT WHEN THE MULTIBEAM IS NOT CALIBRATED

If the multibeam is not calibrated right or not calibrated at all you will find different errors in the data. In the pictures below are the different offsets shown with the errors they give. The pictures with the actual data are some examples from what it may look like if the multibeam is not calibrated when you are processing the survey data.

Latency delay

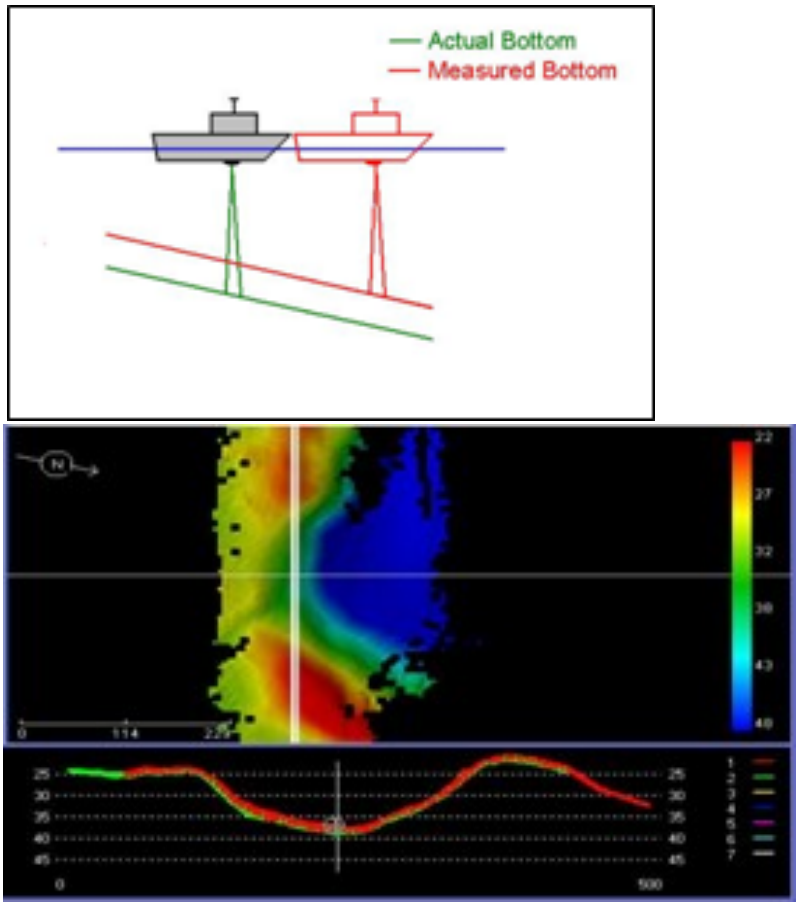


Image 6-7 Error in data latency delay

Latency delay will cause positional errors. The survey data will have a different position from where you actually were during the survey.

Roll

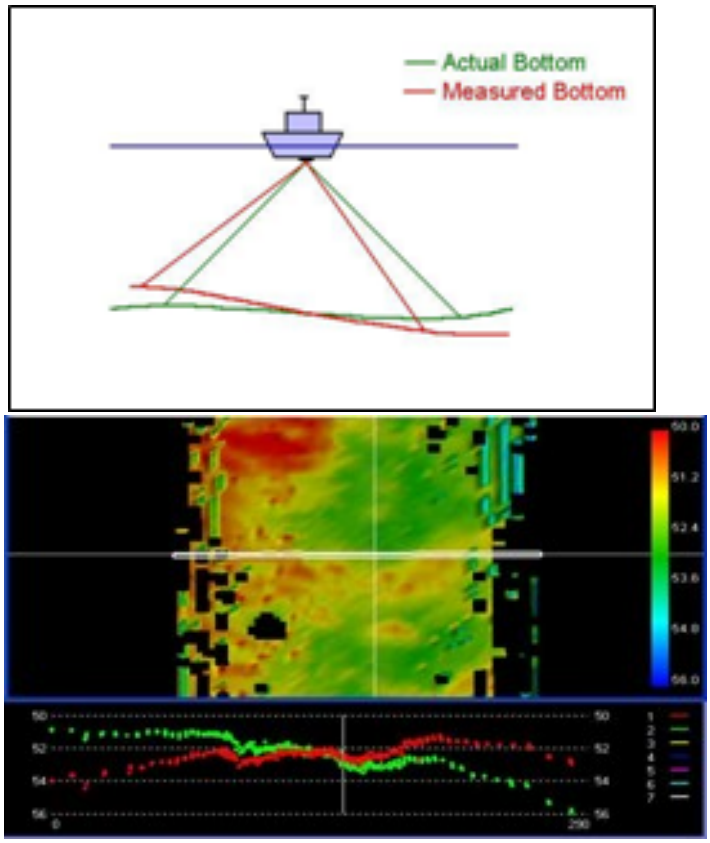
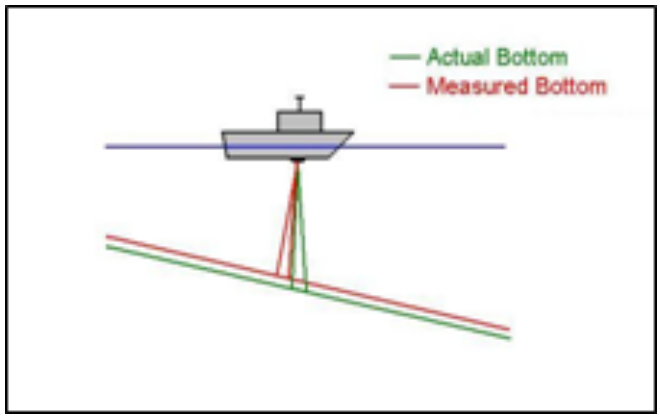


Image 8-9 Error in data roll

Roll will cause large depth errors at outer beams

Pitch



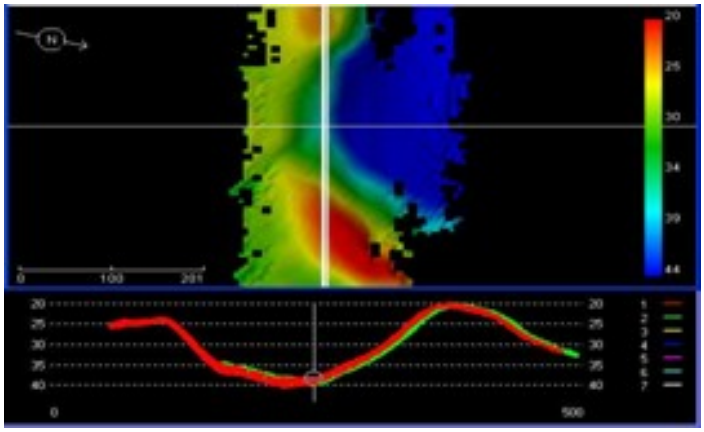
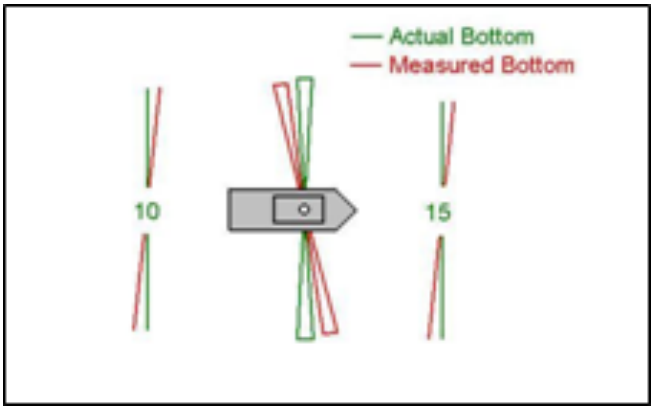


Image 10-11 Error in data pitch

Pitch will cause depth and position errors across the swath

Heading



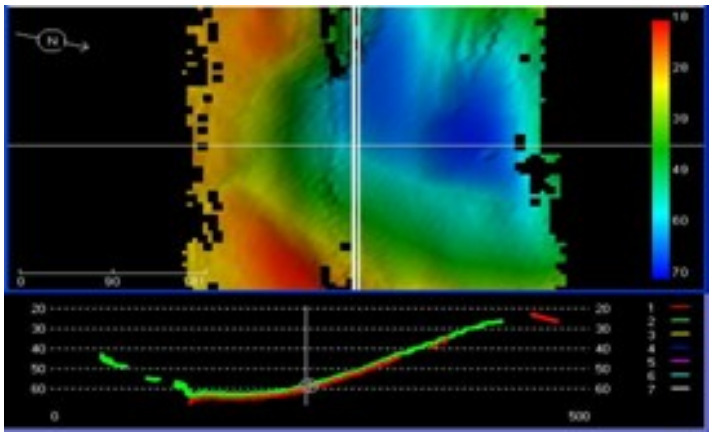


Image 12-13 Error in data heading

Heading will cause position errors. Here you can see why the heading is the most difficult to find because it can look a lot like pitch.

3 PATCHTEST AT SITE

The multibeam used at site is a Kongsberg EM2040C. In the picture below are some features shown to give an indication of what kind of multibeam it is.

Physical	
Size PU (L x W x H):	447 x 178 x 345 mm
Size Transducer: (L x W x H)	Cylindrical: Ø 332 mm Height: 119 mm
Weight PU:	15 kg
Weight Transducer:	23 kg
Working Temp:	-5 to +40°C
Max Operate Depth:	520 m
External Power	
Input Voltage:	115-230 Vac, 50-60 Hz
Consumption:	<250 Watt
Acoustics	
Frequency:	200 to 400 kHz in steps of 10 kHz
Beamwidth: (Along x Across)	2° x 2°at 200 kHz 1° x 1°at 400kHz
Swath Sector:	130°
Max Slant Range:	650 m Max Survey Depth 240m @CW
Max Ping Rate:	50 Hz
Max Resolution:	1.88 cm at 25 µs pulse
Pulse Length:	(CW): 25 – 600 µs (FM): Up to 12 ms
Number of Beams:	160 Equidist/Equiangle 400 High Density
Near-field Focus:	✓
Equiangular beams:	✓
Equidist beams:	✓
Roll Stabilization:	✓
Rotate Sector:	✗

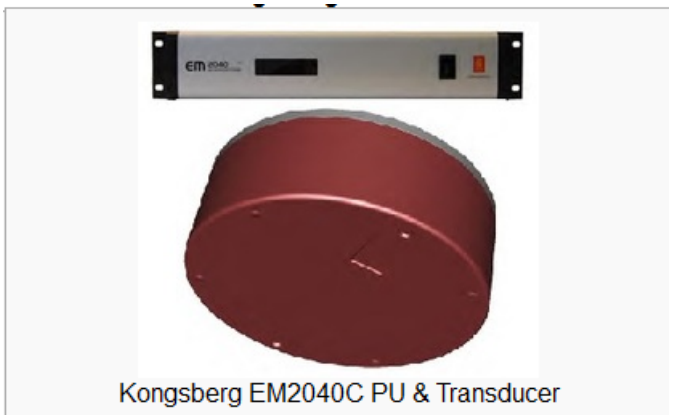

Kongsberg EM2040C PU & Transducer

Image 14-15 Kongsberg EM2040C + features

This multibeam is known for detecting the real seafloor even when there is a lot of noise, so it is great to use at a dredging project. This is because it may occur that there has to be done a survey at the same time the ship is dredging. Dredging causes trouble water.

Image 16 Multibeam installed on arm

Before you can do a patch test you have to find an area with a slope and a flat surface.
Sometimes this can be a bit tricky, because there might be no data of the area that has to be surveyed. Then you have to search the area with the multibeam, which is not yet calibrated, until you find a suitable area.

In the picture below the area is shown where we did the patch test. This area is close to the south entrance of the harbour of Kaohsiung and close to the place where the survey vessel laid. The area had a slope and a flat surface. It did not have a feature.

Image 17 Patch test area

At this project we used the program AutoPatch to find the mounting angle errors for the multibeam. When using AutoPatch the lines you have to sail differ from the lines you have to sail for a 'normal patch test'.
Normally you can sail straight lines to find all the three errors, but when using AutoPatch you also have to sail lines with a turn in it. This is shown in the pictures on the next page.

You have to sail at least 3 lines. 2 lines back and ford for the pitch and roll offsets and 1 line with 50% overlay with the other lines to find the heading. But it is better to sail more lines because AutoPatch can make more combination with more lines and the results will be more accurate. For the calibration we sailed 6 lines. We sailed 4 lines for the pitch and roll and 2 lines for the heading.

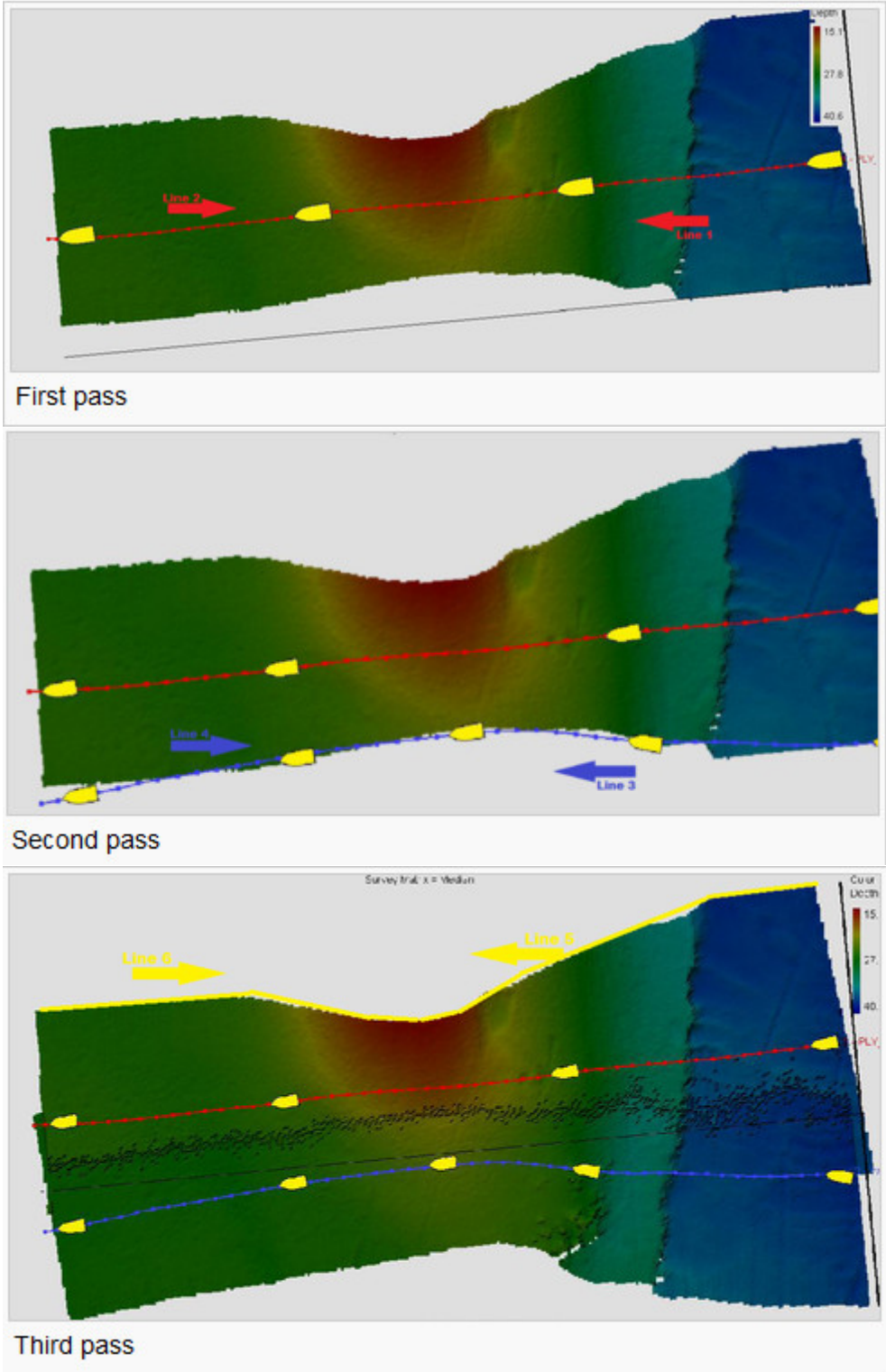


Image 18 Sailing method using AutoPatch

In the pictures above you can see which lines should be sailed with a slight turn in it and which one should be sailed straight.

To do the patch test we used the program ‘AutoPatch’, which is from the same creators as AutoClean. It is a program from BeamworX and is made to find the mounting angle errors of a multibeam.

This program is used, because in contrast to Qinsy, AutoPatch determines if the data of the lines is good enough, what lines he will eventually use for calculating the pitch, roll and heading and what the best location is within every set of sailed lines to calculate the mounting errors. In Qinsy you have to choose the area where you want the program to calculate the roll, pitch and heading by yourself and when you let someone else do the same thing the results may differ. When using AutoPatch you are preventing to calculate different values than your colleagues.

In the picture below you see an example of how processing a patch test looks like in Qimera, the processing program of Qinsy.

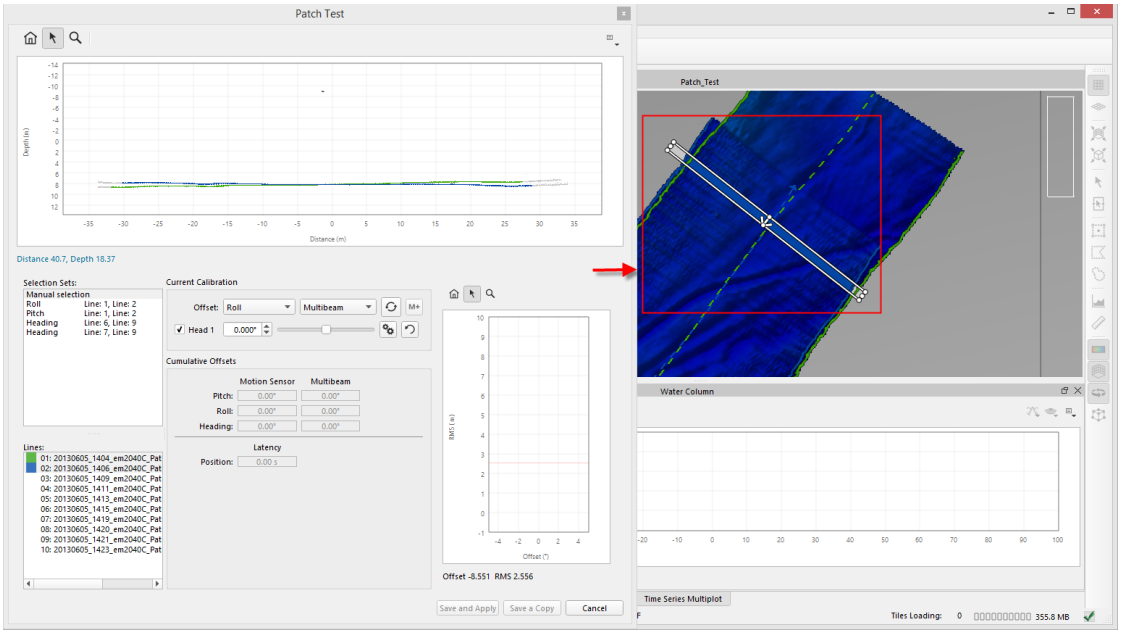
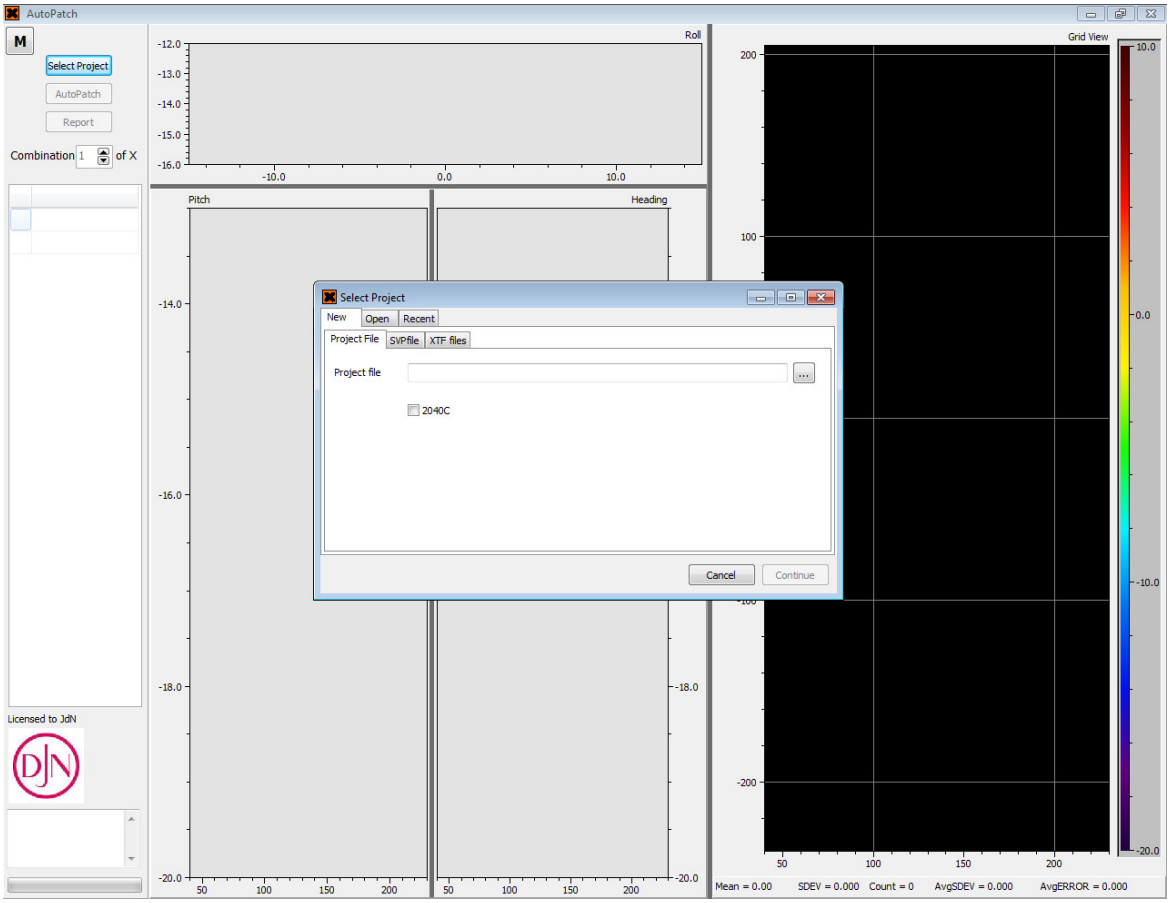


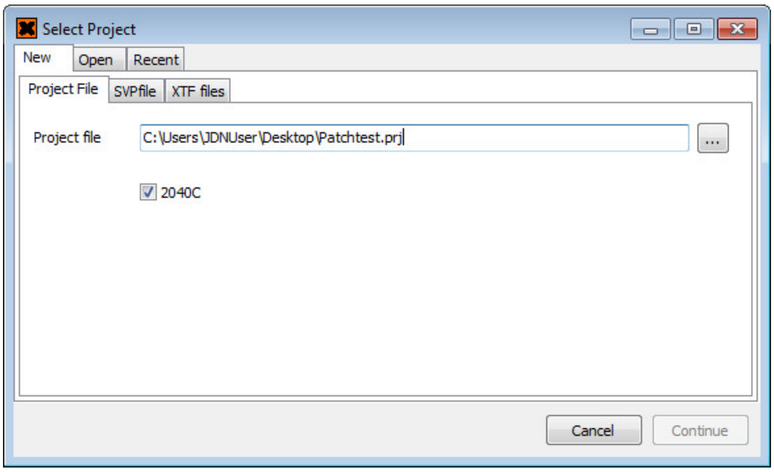
Image 19 Patch test Qimera

4 RESULTS

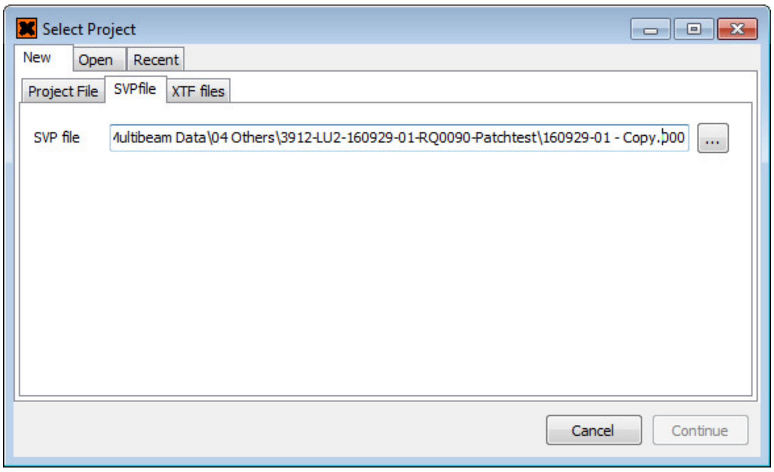
When all the lines are sailed it is time to process the patch test. I will explain how to process the patch test step by step.

Step 1: First of all you have to open AutoPatch and click on 'Select Project'. At the first screen you can choose the name of the Project and if there is used a Multibeam 2040C select this button. At this project we used a Multibeam 2040C.

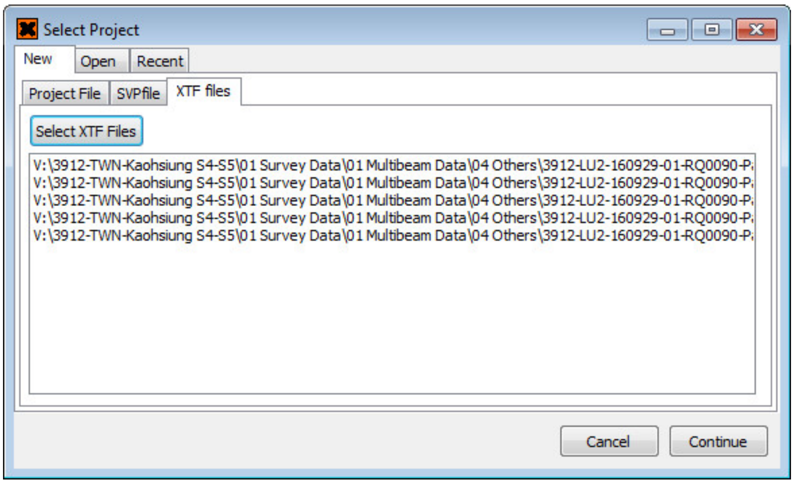




Step 2: Select the SVP file, The SVP file first has to be edited with text editor so the file only contains the sound velocity values with the corresponding depths.

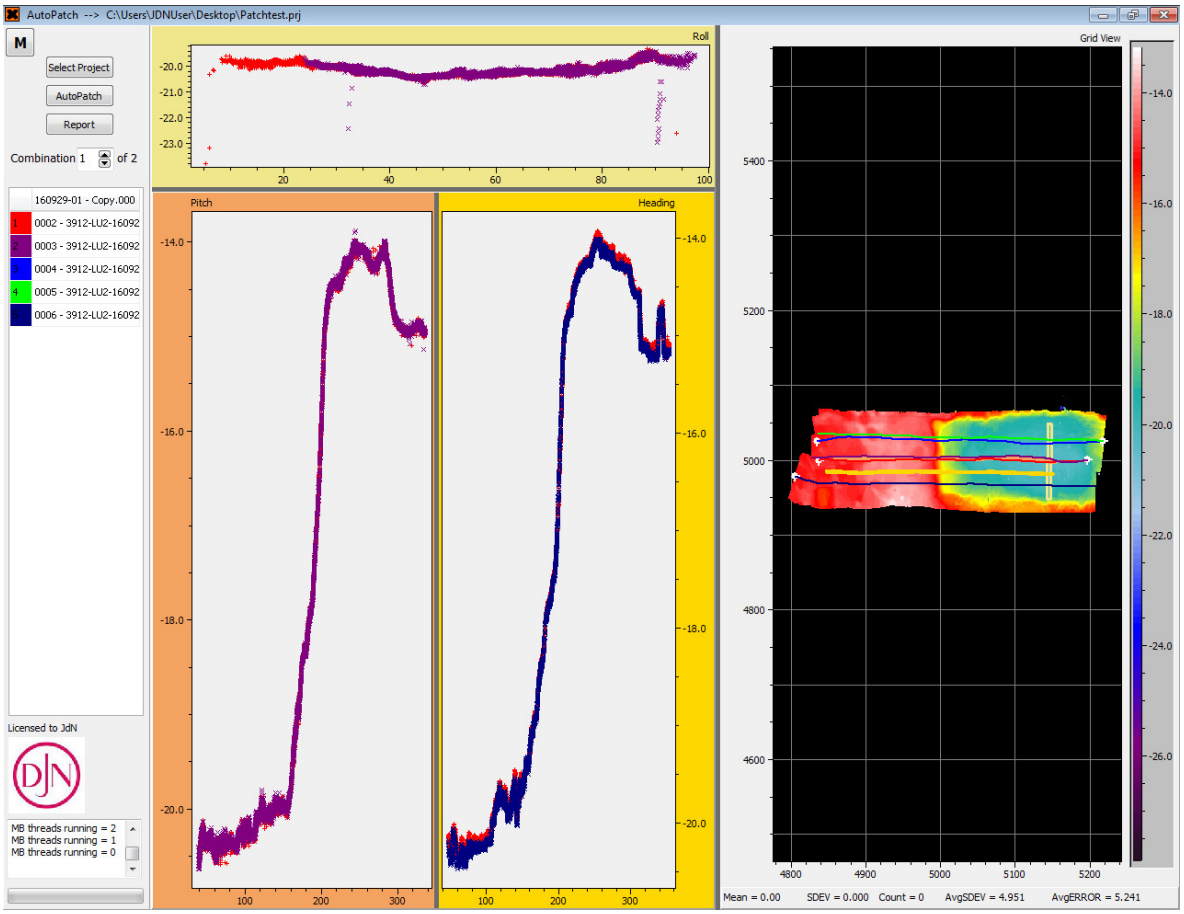


Step 3: Select the survey data. The XTF-files of the data should be selected, otherwise the program will not work. In the previous chapter is mentioned that we sailed 6 lines, but while sailing we came to the conclusion that the data of one line was not accurate because there was an RTK problem. So I didn't use that line in AutoPatch.

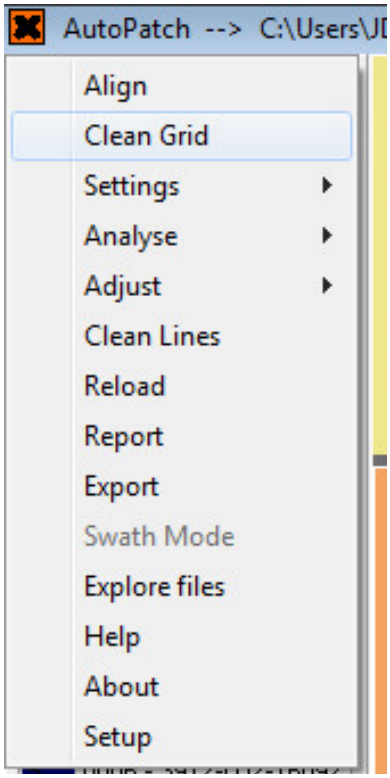


Step 4: Click on continue, then the program will need a bit of time to calculate.

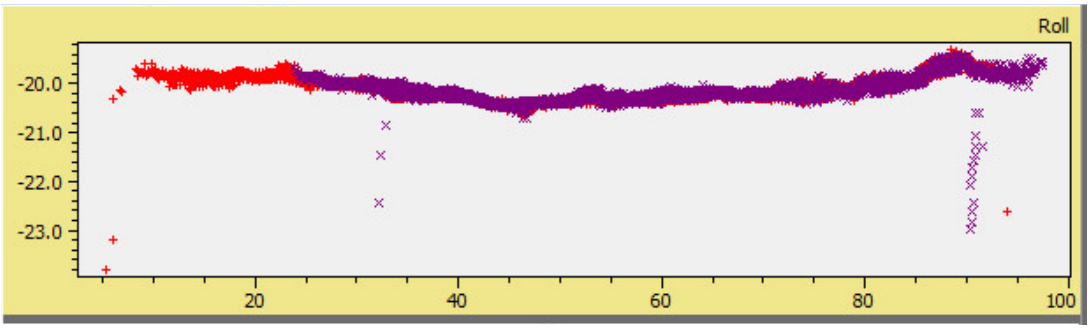
The program determines which lines are used and at what place it will use the data to calculate the values. At the most left of the picture you can see the different lines that are used and also how many combinations the program made. In this example there are 2 combinations made with 5 lines. In the top middle is the data used for the Roll shown. At the bottom left side of the Roll is the Pitch shown and next to the Pitch the Heading is shown. At the most right of the picture you can see the data and which lines and at what place the program chooses to use the data from.

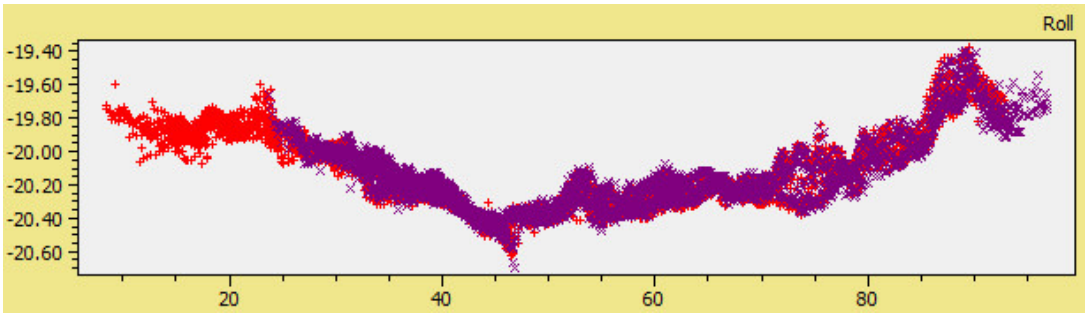


Step 5: Before you start with letting the program calculate the mounting angle errors you can filter the data so any spikes will be deleted. You can filter the data in AutoPatch by clicking on Clean Grid or Clean Lines.

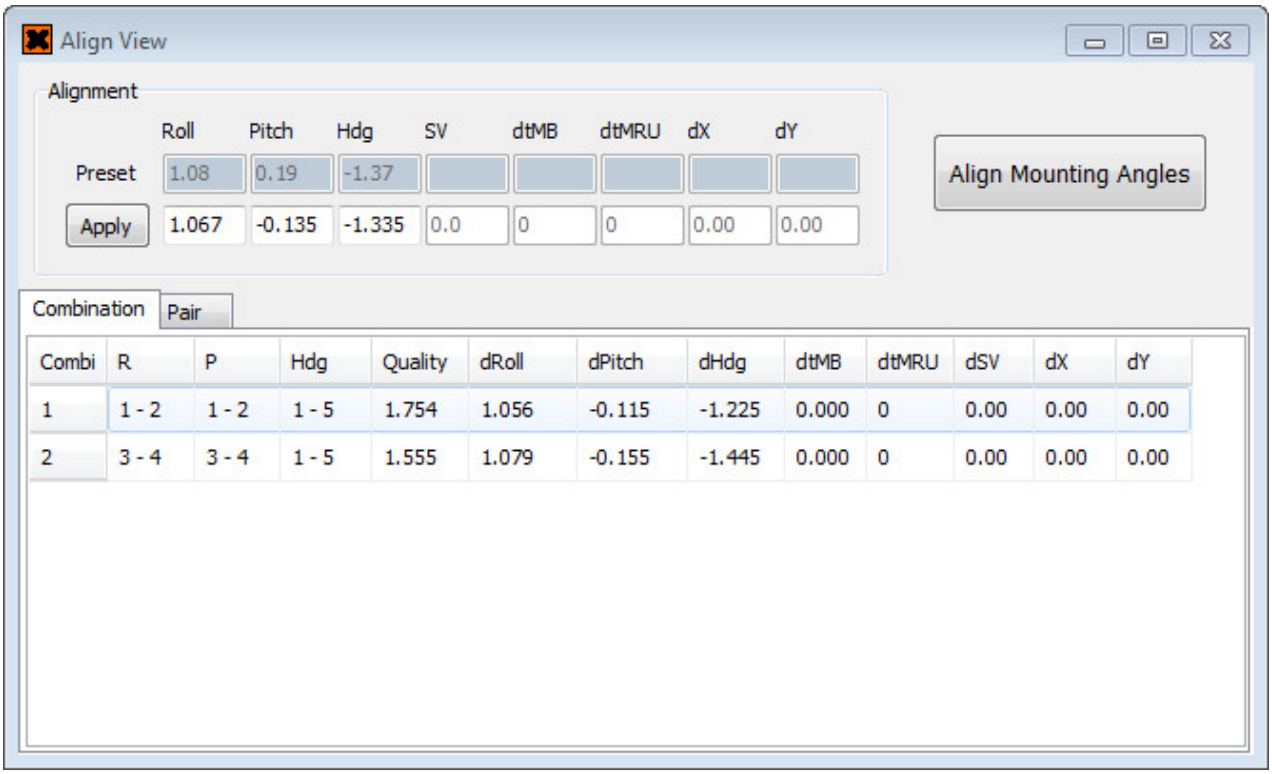


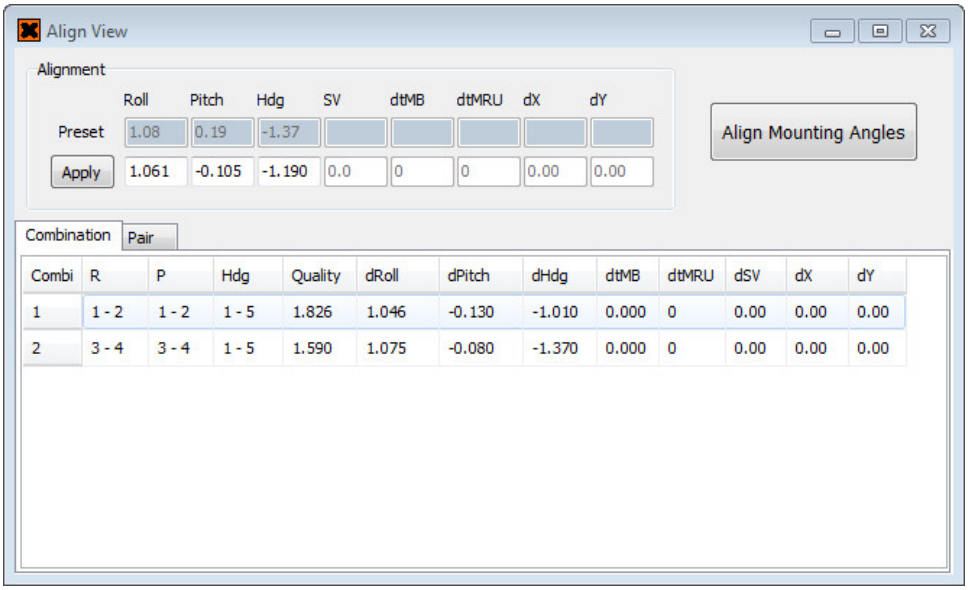
This is an example of the first combination when it is not cleaned and when it is.





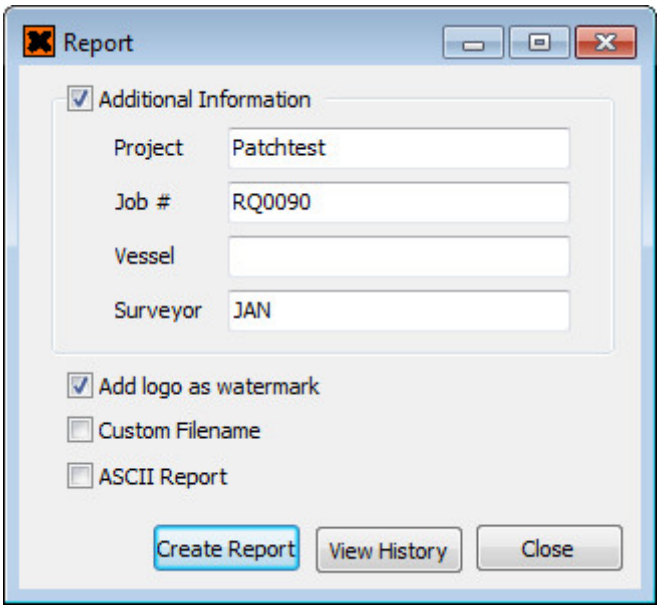
Step 6: When you click on the button Patch test the screen shown below will come forward. These are the values the program calculated for the roll, pitch and heading.
You can see that with the first combination line 1-2 are used to determine the Roll and the Pitch and line 1-5 to determine the heading. In the second combination line 3-4 are used to determine the Roll and Pitch and line 1-5 to determine the heading. To get the values as best as possible you click on apply, the program will then calculate again but using the already calculated values for roll, pitch and heading. After clicking on Apply you click on Align Mounting Angles to let the program calculate the values again. According to the maker of this program this has to be done until the values stop changing after you click on Apply and Align Mounting Angles.





When aligning the mounting angles you will see that the Roll will stay almost the same but that the Pitch and Heading will change quite a bit. This is because the program finds it hard to distinguish the Pitch and the Heading from each other. When you compare the image above and the image on the previous page you can see this.

Step 7: Now you can make a report out of it. Click on report and fill in the information that is requested.



In the report will be shown which lines are used and what the offsets will be on the next page the report is shown. At the bottom the 'new' roll, pitch and heading are shown. Now you can change the offsets of the multibeam into these values.

AutoPatch 9/29/2016 6:06:25 PM Page **1** of **1**

TRANSDUCER ALIGNMENT CALIBRATION		
Current user	:	JDNUser
Project folder	:	C:\Users\JDNUser\Desktop\
Number of XTF files	:	5
Project	:	Patchtest
Job #	:	RQ0090
Vessel	:	
Surveyor	:	JAN

XTF FILE LIST

Date	Start	End	Heading	Speed	File name
29-9-2016	03:22:28	03:24:26	90.2	3.0	0002 - 3912-LU2-160929-01-RQ0090-Progress - 0001.xtf
29-9-2016	03:25:22	03:27:14	270.2	3.3	0003 - 3912-LU2-160929-01-RQ0090-Progress - 0001.xtf
29-9-2016	03:28:26	03:30:32	90.1	3.0	0004 - 3912-LU2-160929-01-RQ0090-Progress - 0001.xtf
29-9-2016	03:31:25	03:33:18	271.4	3.4	0005 - 3912-LU2-160929-01-RQ0090-Progress - 0001.xtf
29-9-2016	03:34:07	03:36:11	91.8	3.2	0006 - 3912-LU2-160929-01-RQ0090-Progress - 0001.xtf

NODE List

Location	X(m)	Y(m)	Z(m)
MRU	0.000	0.000	0.000
Antenna	-0.465	-0.050	6.393
Transducer	0.040	0.004	0.006
Ant→Td	**0.505**	**0.054**	**-6.387**

SOUND VELOCITY FILE

C:\Users\JDNUser\Desktop\160929-01 - Copy.000

33 Records

Min Speed = 1532.0m/s	Min Cast depth = 0.5m	Min Survey depth = 13.2m
Max Speed = 1539.6m/s	Max Cast depth = 16.5m	Max Survey depth = 20.7m

MRU alignment

	Roll°	Pitch°	Heading°
MRU	0.000	0.000	0.000

CALIBRATION OFFSET RESULTS

RP	Hdg	Roll°	Pitch°	Heading°	
1 - 2	**1 - 5**	1.046	-0.130	-1.010	
3 - 4	**1 - 5**	1.075	-0.080	-1.370	
	AVERAGE	**1.06**	**-0.11**	**-1.19**	**ADVISED MOUNTING ANGLES**
	SDEV	0.02	0.04	0.25	

WARNINGS

There are no warnings to report.

Image 20-31 Processing patch test in AutoPatch

In the final report there will be shown which XTF files are used. Also the sound velocity will be shown with the min and max speed and the min depth and max depth.

At the end of the report the most important information is shown. The different combinations that are mad are shown together with the advised mounting angles.

The next step is to change/fill in these offsets in the settings of the multibeam.

5 EPILOGUE

At school we already learned about the calibration of equipment including the multibeam. But since we have no multibeam at school I thought it would be an interesting topic to write a report about and see how a multibeam gets calibrated in 'real life'.
At school we learned about the roll, pitch and heading but I didn't knew that the latency delay also belonged to the patch test.
I also learned that there is a program that can measure these errors by it self, which I think is very handy.

Over all I think I learned a lot by making this report

6 SOURCES

https://nl.wikipedia.org/wiki/Kalibreren
https://en.wikipedia.org/wiki/Calibration
Syllabus – R. van Ree
Surveywiki – Jan de Nul
Simon Steels – Surveyor at site
https://www.deltaohm.nl/home/kalibreren-ijken-justeren-calibreren
http://www.technischwerken.nl/kennisbank/techniek-kennis/wat-is-ijken-en-waar-wordt-ijking-voor-gebruikt/
https://confluence.qps.nl/display/KBE/Howto+Calibrate+a+Multibeam+Echosounder#HowtoCalibrateaMultibeamEchosounder-Resultsofwrongmountingoffsets
http://www.r2sonic.com/pdfs/R2Sonic_ThePatchTest.pdf
http://slideplayer.com/slide/1596461/
http://slideplayer.com/slide/2511860/
https://nl.wikipedia.org/wiki/Multibeam_echolood
https://confluence.qps.nl/display/KBE/Howto+Qimera+-+Processing+a+Patch+Test
http://www.sssi.org.au/userfiles/docs/Hydrography/documents_14755360201084877588.pdf